Bias Correction Methods

Overview

We use a variation of the modified equidistant quantile matching (EDCDFm) algorithm (Li et al. 2010) of (Pierce et al. 2015) to bias correct CMIP5 projections for the Red River, Vietnam. Key differences from (Pierce et al. 2015) include:

- We only apply EDCDFm over wet days when bias correcting precipitation. Unlike (Pierce et al. 2015), this allows a model-predicted increase in number of wet days to be preserved and keeps models with too many historical dry days from being changed to all wet days over the historical period when biased corrected.
- We do not apply the frequency-dependent bias correction method described in section 4 of (Pierce et al. 2015).
- If bias correction is applied without a moving time window, it will correct extremes, but not the annual cycle. Conversely, if bias correction is applied over a small moving window, it will correct the annual cycle, but may not correctly represent extremes. This is especially true for the EDCDFm method. To balance the correction of extremes and the annual cycle, (Pierce et al. 2015) use a "preconditioning" step and an iterative application of EDCDFm over different moving window sizes (section 5). We use an alternative method. We first bias correct with EDCDFm using a 31-day moving window. We then bias correct with EDCDFm without a moving window. Finally, we bias correct the values from the 31-day moving window bias correction using those from the bias correction without a moving window.

Details of the Red River variation of EDCDFm are provided below.

Symbols

W_t	precipitation wet day threshold
K	precipitation change correction factor
x	change in mean precipitation as a ratio
x_{bc}	change in mean precipitation as a ratio for bias-corrected values
O_{base}	observations for historical base time period
M_{base}	modeled values for historical base time period
M_{fut}	modeled values for time period to bias correct
Δ	predicted change in value at a given quantile

General Steps

1. Set training base period (~30 year period) for which there are both observed and modeled values. Example: 1976-2005.
2. Set time periods to bias correct individually (~30 year periods). Example: 1976-2005, 2006-2039, 2040-2069, 2070-2099

3. Loop through all time periods to bias correct
    a. Apply bias correction to a single time period
        i. Apply bias correction on a moving window. Loop through all days-of-year (366 total)
            1. Apply bias correction to a single day-of-year
                a. Get all observations and modeled values from base period that are within 15 days of the day-of-year (31-day moving window)
                b. Get all modeled values from time period to bias correct that are within 15 days of the day-of-year (31-day moving window)
                c. Run specified bias correction method for day-of-year using *a.* and *b.* as input
        ii. Run specified bias correction method over entire time period to bias correct without a moving window
        iii. Bias correct *i.* with *ii.* using specified bias correction method. This is the final bias corrected output for the time period.

Precipitation Bias Correction Method

1. Find wet day threshold, W_t, such that applying W_t makes the model's number of wet days match the number of observed wet days over the training base period if all observations at or below W_t are set to 0-mm. This fixes wet biases (too many wet days), but cannot adjust for dry biases (not enough wet days). If a model is dry biased, W_t is set to 0-mm.
2. Set all model precipitation values <= W_t to 0-mm in the both the training base period and the time period to bias correct.
3. Apply equidistant quantile matching to modeled values in time period to bias correct using only wet days from both the observations and the model values.
4. Calculate correction factor, K, to preserve modeled mean change in precipitation in the biased corrected values.
    a. Calculate mean precipitation change, x, as a ratio between non-bias corrected but W_t corrected modeled values in base period and non-bias corrected but W_t corrected modeled values in the time period to bias correct.
    b. Apply equidistant quantile matching to modeled values in training base period using only wet days from both the observations and the model values.
    c. Calculate mean precipitation change, x_{bc}, as a ratio between bias-corrected modeled values in training base period and bias-corrected model values in the time period to bias correct.
    d. Calculate correction factor as: $K = x / x_{bc}$
5. Multiply all bias-corrected values in time period to bias correct by K

Temperature Bias Correction Method

1. Apply equidistant quantile matching to modeled values in time period to bias correct

Equidistant Quantile Matching

1. Calculate empirical cumulative distribution function for training base period observations, $\boldsymbol{O}_{base}$, training base period modeled values, $\boldsymbol{M}_{base}$, and modeled values from time period to bias correct, $\boldsymbol{M}_{fut}$.
2. Map each value in $\boldsymbol{M}_{fut}$ to corresponding value in $\boldsymbol{M}_{base}$ based on percentile. For instance, the 45th percentile value in $\boldsymbol{M}_{fut}$ is mapped to the 45th percentile value in $\boldsymbol{M}_{base}$
3. Get difference, Δ, for each value mapping. For temperature, Δ is an additive difference, $\boldsymbol{M}_{fut} - \boldsymbol{M}_{base}$. For precipitation, Δ is a ratio difference, $\boldsymbol{M}_{fut} / \boldsymbol{M}_{base}$.
4. Map each value in $\boldsymbol{M}_{fut}$ to corresponding value in $\boldsymbol{O}_{base}$ based on percentile.
5. Apply corresponding Δ for each $\boldsymbol{M}_{fut}$ to corresponding mapped $\boldsymbol{O}_{base}$ value to get biased corrected values, $\boldsymbol{M}_{bc}$. For temperature, $\boldsymbol{M}_{bc} = \boldsymbol{O}_{base} + \Delta$. For precipitation, $\boldsymbol{M}_{bc} = \boldsymbol{O}_{base} \times \Delta$.

References

Li, H., J. Sheffield, and E. F. Wood, 2010: Bias correction of monthly precipitation and temperature fields from Intergovernmental Panel on Climate Change AR4 models using equidistant quantile matching. *J. Geophys. Res. D: Atmos.*, **115**, doi:10.1029/2009JD012882. http://dx.doi.org/10.1029/2009JD012882.

Pierce, D. W., D. R. Cayan, E. P. Maurer, J. T. Abatzoglou, and K. C. Hegewisch, 2015: Improved Bias Correction Techniques for Hydrological Simulations of Climate Change. *J. Hydrometeorol.*, **16**, 2421–2442.